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# Some Psycho-Physiological and Cognitive Implications of Hypobaric Exposure during Selection of Slovak Astronaut Candidates

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***Abstract***

During September and October of 1997, the Military Aviation Hospital in Kosice was entrusted by the Head of the Slovak Air force to select appropriate astronaut candidates for space flight and stay at the Russian Space Station "MIR" from 26 applicants (experienced elite fighter pilots of the Slovak Air Force) to be placed in a mixed international crew (Slovak, Russian and French). A resulting seven-day mission of the first Slovak astronaut in February 1999 was successfully completed. Part of the medical-psycho-physiological selection of applicants was exposure to hypobaric chamber conditions. During a 20-minute exposure to 7,600m (25,000 ft.) of altitude their cognitive capacity was tested (by simplified mathematical tasks) and correlated with other tests of mental capability. The behavioural and mood changes were continuously observed and recorded. Achieved findings were used for the assessment of hypobaric mental work ability of the astronaut candidates. Before and after the hypobaric exposure we took applicants blood samples in order to estimate blood oxygen saturation.


*Fig. 1*

***Keywords:*** *hypoxia, personality and cognitive processes.*

## *Introduction*

Several studies on hypobaric exposure and extreme hypoxia describe the changes in cognitive performance and psychic states (2, 6, 9, 10).

The most typical changes in psychological states during hypoxia are elation, euphoria, overconfidence and lack of discipline, risky behaviour, higher level of aggression through loss of control, irresponsibility and senselessness. Concerning the effects of hypoxia on cognitive functions, there is a typical performance decrement, difficulty in concentrating and faulty judgement (5, 6, 7, 10). It is well recognised that performance in an hypoxic state does not suddenly change from normal functioning to uselessness, but rather that there exists a progressive performance deterioration, reflecting the arterial blood oxygen saturation. Various aspects of human perception including vision and hearing are sensitive to hypoxia. Another well-known characteristic of hypoxia is that it slows the responding and prolongs the reaction time (4, 5).

Temporary impairments in cognitive functioning found at high altitude include deterioration of the ability to learn, remember and express information verbally, impaired concentration and cognitive flexibility, decline in feeling of knowing, and mild impairment in either short-term memory or conceptual tasks. Other studies reported impairments in grammatical reasoning and in pattern comparison during a slow, multi-day, simulated ascent in the hypobaric chamber. Some cognitive deficits found after high altitude expeditions include decreased memory performance, mild impairment in concentration, verbal learning and memory, and cognitive flexibility. In general many authors agree that high altitude hypoxia is stressful. During acute hypoxia, psychological processes (affective and cognitive) and in particular intellectual abilities appear to be altered. During the second period the subject begins to adapt and should improve. To

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compensate for this decline, the subject may implement conscious and unconscious strategies that allow them to cope and adapt (2).
In our study we suppose that there exists psycho-physiological and cognitive qualities that may be specific predictors of psychological changes during hypoxia.

**Fig. 2 HYPOBARIC CHAMBER EXPOSURE PROFILE**

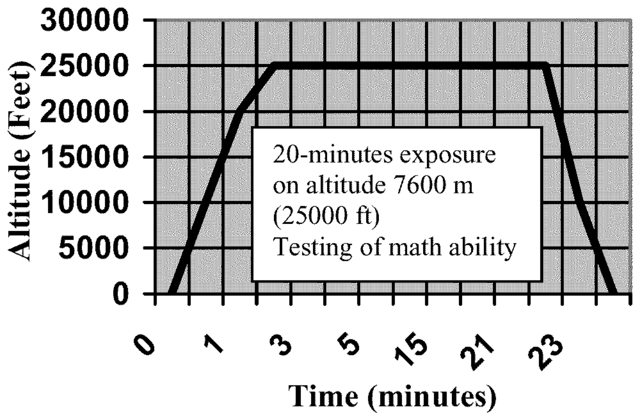


*Fig. 3 Hypobaric chamber exposure*

### *Methods*

*Subjects*: 26 male volunteers, experienced jet fighter pilots, age range of 23-42 years and a military aviation academy education.
*Procedure*: All subjects were tested during medical-psychological pre-selection of candidates in the Military Aviation Hospital in Košice. An examination under hypobaric conditions was performed in the hypobaric chamber instaled at the Military Aviation Academy in Košice.
*Cognitive tests:* With the view of this study, achieved results selected from sub-tests of Intelligence Structure Test by Amthauer (1) - (ME) memory, (AR) arithmetic and (NU) numerical reasoning and Co-ordination Precision Analyser (AKP) - complex reaction time and error rate, spatial orientation test (OR1, OR 3) were used. The test of simple math ability (summation, subtraction, multiplication and division - MATH) during hypobaric exposure was applied. We scored a number of correct results and errors.
*Motivation*: Supplementary performance motivation was measured by the performance motivation questionnaire (11).
*Personality:* Personality traits were tested by the SPIDO questionnaire (8). Four basic factors KO (cognitive variability), EM (emotional variability), RG (self-regulative variability) and AD (adaptative variability) were correlated with the math performance results in hypobaric conditions (Tab. 1.).

**Tab. 1 Meanings of the SPIDO basic factors**

| **Factors** | **(+) high score** | **(-) low score** |
|---|---|---|
| KO - cognitive variability concerning the ability to perceive and process the situational environment variables | + tendency to search for a change, quality and variability of intensive external stimulation in their perception and complex processing | - tendency to search for more stable interactions with more stable environment |
| EM - emotional variability concerning emotional response in interaction to environment and situational variables | + high emotional excitability, tendency to feel situational tension | - emotional stability, very low emotionality |
| RG - regulative variability concerned with regulation of behavioural function and self-control | + low self-control, self-regulation, low anticipation of possible consequences in behaviour | - very high anticipation and regulation of own decision making and behaviour |
| AD - adaptive variability concerning the tendency to adaptive behaviour into new environment and life events | + high tendency to adaptive behaviour in dynamic environment | - very low adaptability, |

Testing in hypobaric chamber conditions: 26 applicants were tested in the hypobaric conditions of chamber PBK-53 during a two week period. The number of examined persons in the hypobaric chamber at the same time was 3 or 4, as well as an aviation physician who monitored health and psycho-physiological conditions and administered the form of the math tests. The Ascent speed from normobaric to hypobaric condition (7,600m) was 3m/sec ad the descent from hypobaria to normobaria was 5m/sec. The total examination time in hypobaric conditions was about 25 minutes and exposure to 7,600m of altitude took 20 minutes. Within 20 minutes of hypoxia a simple math test was administered (see Fig.2). Before and immediately after hypobaric exposure blood samples were taken in order to estimate blood oxygen saturation (Tab. 3).

*Direct observation and checking:* all subjects were observed and checked by the aviation physician and the aviation psychologist, who carried out all examinations during hypobaric exposure. An aviation physician was inside the chamber with oxygen supply and the aviation psychologist monitored behavioural changes from outside through sights and intercom. Possible significant behavioural changes have been recorded (Tab. 5).

## *Results*

Statistical comparison of mean $SaO_2$ in normobaric and post-hypobaric conditions (Tab 2.) Based on laboratory analyse of capillar blood flow shows high significance ($p>0.0001$) between normobaria and hypobaria.

**Tab. 2**

| **Blood oxygen saturation $SaO_2$ n=26** | **Normobaric $aO_2$** | **Post-hypobaric $SaO_2$** |
|---|---|---|
| **Mean** | 92,1 % | 88,0 % |
| **Minimum - Maximum** | 86,4 % - 95,8 % | 66,8 % - 93,7 % |
| **T-test (level of significance)** | p > 0.0001 | |

Significant effect of hypobaria ($F=4.45$, $p=0.037$) on math performance have indicated statistical comparison between those subjects with different $SaO_2$ (Table 3.)

**Tab. 3**

| **Variable MATH in hypobaria** | **Number of cases** | **Mean** | **SD** | **Statistic significance level** |
|---|---|---|---|---|
| **Group 1 $SaO_2$ 66.8 % - 89.4 %** | 14 | 55.5714 | 25.542 | F = 4.868<br>P = 0. 037* |
| **Group 2 $SaO_2$ 90 % - 93.7 %** | 12 | 67.5833 | 17.474 | |

As aforesaid we supposed a statistically significant effect of general cognitive abilities in normobaria on math performance during hypoxia. Statistically significant relations were found between parameters AKP 1 E - errors in normobaria and MATH 1 - errors in hypobaria (p=0.009), AKP 1 R- reaction time and MATH 1 - errors (p=0.04), AKP 2 - errors in complex reactions and MATH 1 - errors (p=0.05) and AKP 2 R-complex reaction time and MATH 2 - math performance accuracy.

Considerable findings were found by statistically significant relations between MV - performance motivation and MATH 2 - hypobaric math performance accuracy (p=0.05), between AB - performance braking activities and MATH 1 - hypobaric math error rate (p=0.046) and between KO - cognitive variability and MATH 2 - hypobaric math performance accuracy (p=0.038). Correlation coefficients of cognitive and personality tests and the math performance test carried out in hypobaric conditions (see Tab. 4).

**Tab. 4**

| Tests of cognitive ability and personality traits (normobaric conditions) | MATH 1 Math performance Errors (hypobaric conditions) | MATH 2 Math performance Accuracy (hypobaric conditions) |
|---|---|---|
| **AKP 1 E ( error rate)** | 0.4594 **p=0.009*** ** | 0.1631 p=0.213 |
| **AKP 1R (reaction time)** | 0.3503 **p=0.04** ** | 0.1631 p=0.213 |
| **AKP 2 E (error rate)** | 0.3155 **p=0.05*** | -0.1405 p=0.247 |
| **AKP 2R (complex reaction time)** | 0.1855 p=0.182 | 0.3775 **p=0.029** ** |
| **IST ME (memory)** | 0.1532 p=0.227 | 0.2320 p=0.127 |
| **IST AR (arithmetic ability)** | 0.1020 p=0.31 | 0.0626 p=0.381 |
| **IST NU (numeric ability)** | 0.1229 p=0.275 | -0.1642 p=0.211 |
| **OR 1 (spatial orientation ability)** | 0.1641 p=0.212 | 0.2198 p=0.140 |
| **OR 3 (spatial orientation ability)** | 0.1429 p=0.243 | 0.1645 p=0.211 |
| **MV (performance motivation)** | -0.0412 p=0.421 | 0.3181 **p=0.05*** |
| **AP (performance supporting activities)** | -0.0556 p=0.394 | 0.1291 p=0.265 |
| **AB (performance braking activities)** | -0.3381 **p=0.046*** | -0.1569 p=0.222 |
| **KO Cognitive variability** | -0.1380 p=0.251 | 0.3536 **p=0.038** ** |
| **EM Emotional variability** | -0.396 p=0.424 | 0,0034 p=0.493 |
| **RG Regulative variability** | -0.0709 p=0.365 | -0.2118 p=0.149 |
| **AD Adaptive variability** | 0.0362 p=0.430 | 0.303 p=0.442 |

During hypobaric exposure we observed and checked all 26 subjects and remarkable behavioural symptoms were recorded:

**Tab. 5**

| Behavioural symptoms of hypoxia | Within 10-min of hypobaric exposure Number of subjects | Until the end of hypobaric exposure Number of subjects |
|---|---|---|
| **Hyperventilation** | 2 | 10 |
| **Sweating** | 4 | 5 |
| **Deceleration of reactions** | 5 | 15 |
| **Feeling of well being or euphoria** | 3 | 10 |
| **Loss of control** | 1 | 1 |
| **Sleepiness** | 1 | 1 |
| **Cyanosis** | 1 | 1 |
| **Loss of consciousness** | - | - |

The altitude chamber gives the opportunity to experience and observe symptoms of hypoxia under controlled conditions. In the event of the last four symptoms occurring (e.g. cyanosis, sleepiness, loss of control or consciousness) math testing in hypobaric conditions would have been stopped and oxygen

supply immediately recovered. Subjects with manifestation of these serious symptoms during hypobaric exposure were rejected. During the hypoxia exposure, nobody lost consciousness.

## *Conclusion*

On the basis of these findings it can be stated that the error rate as a cognitive aspect in normobaria has a statistically significant effect on operational error rate in hypobaric conditions and could be used as a psychological predictor of operational aptitudes in time of useful consciousness. Similar findings could be stated for reaction time in relation to math performance accuracy. There are also personality traits - cognitive variability and performance motivation, that have significant influence on cognitive performance in general and consequently on cognitive processes in hypobaric conditions. However, we acknowledge that hypobaric conditions and hypoxia have significant influence on the reduction of cognitive aptitudes. Higher levels of operational cognitive aptitudes and performance motivation in general has positive influence on operational performance in time of useful consciousness.

We understand our findings are also supporting the idea, that time of useful consciousness and mental operational performance could be increased by means of quality and demanding personality assessment and systematic training in coping with hypobaric conditions.

We appreciate the necessity of further application and comparing the identical mental performance tests in normobaria and hypobaria, which could give us a more exact answer on formulated hypothesis. In the possible event of the ability to simulate the effect of hypoxia in an operational environment (e.g. the cockpit of an aircraft simulator), this could be a challenge for the next pilot selection programme, also for the research and development of training equipment in aviation.

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